(b) The barrier is traveling at any speed up to and including 30 mph with its face perpendicular to the longitudinal centerline of the vehicle; and

(c) A vertical plane through the geometric center of the barrier impact surface and perpendicular to that surface coincides with the longitudinal centerline of the vehicle.

S7.4 *Moving contoured barrier test conditions.* The moving contoured barrier crash test conditions are those specified in S7.5 of Standard No. 301, 49 CFR 571.301.

[59 FR 19659, Apr. 25, 1994; as amended at 60 FR 2543, Jan. 10, 1995; 60 FR 57948, Nov. 24, 1995]

§ 571.304 Standard No. 304; Compressed natural gas fuel container integrity.

S1. *Scope.* This standard specifies requirements for the integrity of compressed natural gas (CNG), motor vehicle fuel containers.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries occurring from fires that result from fuel leakage during and after motor vehicle crashes.

S3. *Application.* This standard applies to containers designed to store CNG as motor fuel on-board any motor vehicle.

S4. *Definitions.*

Brazing means a group of welding processes wherein coalescence is produced by heating to a suitable temperature above 800 ° F and by using a nonferrous filler metal, having a melting point below that to the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

Burst pressure means the highest internal pressure reached in a CNG fuel container during a burst test at a temperature of 21 ° C (70 ° F).

CNG fuel container means a container designed to store CNG as motor fuel on-board a motor vehicle.

Fill pressure means the internal pressure of a CNG fuel container attained at the time of filling. Fill pressure varies according to the gas temperature in the container which is dependent on the charging parameters and the ambient conditions.

Full wrapped means applying the reinforcement of a filament or resin system over the entire liner, including the domes.

Hoop wrapped means winding of filament in a substantially circumferential pattern over the cylindrical portion of the liner so that the filament does not transmit any significant stresses in a direction parallel to the cylinder longitudinal axis.

Hydrostatic pressure means the internal pressure to which a CNG fuel container is taken during testing set forth in S5.4.1.

Liner means the inner gas tight container or gas cylinder to which the overwrap is applied.

Service pressure means the internal settled pressure of a CNG fuel container at a uniform gas temperature of 21 ° C (70 ° F) and full gas content. It is the pressure for which the container has been constructed under normal conditions.

Stress ratio means the stress in the fiber at minimum burst pressure divided by the stress in the fiber at service pressure.

S5 *Container and material requirements.*

S5.1 *Container designations.* Container designations are as follows:

S5.1.1 *Type 1—Non-composite metallic container* means a metal container.

S5.1.2 *Type 2—Composite metallic hoop wrapped container* means a metal liner reinforced with resin impregnated continuous filament that is ''hoop wrapped.''

S5.1.3 *Type 3—Composite metallic full wrapped container* means a metal liner reinforced with resin impregnated continuous filament that is ''full wrapped.''

S5.1.4 *Type 4—Composite non-metallic full wrapped container* means resin impregnated continuous filament with a non-metallic liner ''full wrapped.''

S5.2 *Material designations.*

S5.2.1 *Steel containers and liners.*

(a) Steel containers and liners shall be of uniform quality. Only the basic oxygen or electric furnace processes are authorized. The steel shall be aluminum killed and produced to predominantly fine grain practice. The steel heat analysis shall be in conformance with one of the following grades:

TABLE ONE—STEEL HEAT ANALYSIS

Grade element	Chrome-Molybdenum percent	Carbon-Boron percent	Carbon-Manganese percent
Carbon	0.25 to 0.38	0.27 to 0.37	0.40 max.
Manganese	0.40 to 1.05	0.80 to 1.40	1.65 max.
Phosphorus	0.015 max	0.015 max	0.025 max.
Sulfur	0.010 max	0.010 max	0.010 max.
Silicon	0.15 to 0.35	0.30 max	0.10/0.30
Chromium	0.80 to 1.15	N/A	N/A
Molybdenum	0.15 to 0.25	N/A	N/A
Boron	N/A	0.0005 to 0.003	N/A
Aluminum	0.02 to 0.07	0.02 to 0.07	0.02/0.07

[1] "N/A" means not applicable.

(b) Incidental elements shall be within the limits specified in the *Standard Specification for Steel, Sheet and Strip, Alloy, Hot-Rolled and Cold-Rolled, General Requirements for* ASTM A 505 (1987).

S5.2.1.1 When carbon-boron steel is used, the test specimen is subject to a hardenability test in accordance with the *Standard Method for End-Quench Test For Hardenability of Steel,* ASTM A 255 (1989). The hardness evaluation is made 7.9 mm (5⁄16 inch) from the quenched end of the Jominy quench bar.

S5.2.1.2 The test specimen's hardness shall be at least Rc (Rockwell Hardness) 33 and no more than Rc 53.

S5.2.2 *Aluminum containers and aluminum liners.* (Type 1, Type 2 and Type 3) shall be 6010 alloy, 6061 alloy, and T6 temper. The aluminum heat analysis shall be in conformance with one of the following grades:

TABLE TWO—ALUMINUM HEAT ANALYSIS

Grade element	6010 alloy percent	6061 alloy percent
Magnesium	0.6 to 1.0	0.8 to 1.2.
Silicon	0.8 to 1.2	0.40 to 0.8.
Copper	0.15 to 0.6	0.15 to 0.40.
Chromium	0.10 max	0.04 to 0.35.
Iron	0.50 max	0.7 max.
Titanium	0.10 max	0.15 max.
Manganese	0.20 to 0.8	0.15 max.
Zinc	0.25 max	0.25 max.
Others, Each [1]	0.05 max	0.05 max.
Others, Total [1,2]	0.15 max	0.15 max.
Aluminum min..	Remainder...	Remainder.

[1] "Others" includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the registration or specification. However, such analysis is not required and may not cover all metallic "other" elements. Should any analysis by the producer or purchaser establish that an "others" element exceeds the limit of "Each" or that the aggregate of several "others" elements exceeds the limit of "Total," the material shall be considered non-conforming.

[2] The sum of those "Others" metallic elements 0.010 percent or more each, expressed to the second decimal before determining the sum.

(Registration Record of Aluminum Association Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys, The Aluminum Association, Inc. Rev. Dec. 1993)

S5.2.3 Structural reinforcing filament material shall be commercial grade E-glass, commercial grade S-glass, aramid fiber or carbon fiber. Filament strength shall be tested in accordance with the *Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics,* ASTM D 2343 (1967, Reapproved 1985), or SACMA *Recommended Test Method for Tow Tensile Testing of Carbon Fibers,* SRM 16–90, 1990. Fiber coupling agents (sizing) shall be compatible with the resin system. If carbon fiber reinforcement is used the design shall incorporate means to prevent galvanic corrosion of metallic components of the fuel container.

S5.2.4 The resin system shall be epoxy, modified epoxy, polyester, vinyl ester or thermoplastic.

S5.2.4.1 The resin system is tested on a sample coupon representative of the composite overwrap in accordance with the *Standard Test Method for Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method,* ASTM D 2344, (1984, Reapproved 1989) following a 24-hour water boil.

S5.2.4.2 The test specimen shall have a shear strength of at least 13.8 MPa (2,000 psi).

S5.2.5 For nonmetallic liners, the permeation of CNG through the finished container's wall at service pressure is less than 0.25 normal cubic centimeters per hour per liter water capacity of the container.

S5.3 *Manufacturing processes for composite containers.*

S5.3.1 *Composite containers with metallic liners.* The CNG fuel container shall be manufactured from a metal liner overwrapped with resin impregnated continuous filament windings, applied under controlled tension to develop the design composite thickness. After winding is complete, composites using thermoset resins shall be cured by a controlled temperature process.

S5.3.1.1 *Type 2 containers.* Type 2 containers shall have a hoop wrapped winding pattern.

S5.3.1.2 *Type 3 containers.* Type 3 containers shall have a full wrapped ''helical or in plane'' and a ''hoop'' wrap winding pattern.

S5.3.2 Type 4 containers. Composite containers with nonmetallic liners shall be fabricated from a nonmetallic liner overwrapped with resin impregnated continuous filament windings. The winding pattern shall be ''helical or in plane'' and ''hoop'' wrap applied pattern under controlled tension to develop the design composite thickness. After winding is complete, the composite shall be cured by a controlled temperature process.

S5.3.3 *Brazing.* Brazing is prohibited.

S5.3.4 Welding. Welding shall be done in accordance with the *American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code,* Section IX, Article II, QW–304 and QW–305 (1992). Weld efficiencies shall be in accordance with *ASME Boiler and Pressure Vessel Code,* Section VIII, UW–12 (1989). Any weld shall be subject to full radiographic requirements in accordance with *ASME Boiler and Pressure Vessel Code,* Section VIII, UW–51 thru UW–53 (1989). For Type 2 and Type 3 liners, longitudinal welds and nonconsumable backing strips or rings shall be prohibited.

S5.4 *Wall thickness.*

S5.4.1 *Type 1 Containers.*

(a) The wall thickness of a Type 1 container shall be at least an amount such that the wall stress at the minimum prescribed hydrostatic test presure does not exceed 67 percent of the minimum tensile strength of the metal as determined by the mechanical properties specified in S5.7 and S5.7.1.

(b) For minimum wall thickness calculations, the following formula is used:

$$S = \frac{P\left(1.3D^2 + 0.4d^2\right)}{\left(D^2 - d^2\right)}$$

Where:

S = Wall stress in MPa (psi).

P = Minimum hydrostatic test pressure in Mpa (psi).

D = Outside diameter in mm (inches).

d = Inside diameter in mm (inches).

S5.4.2 *Type 2 containers.*

S5.4.2.1 The wall thickness of a liner to a Type 2 container shall be at least an amount such that the longitudinal tensile stress at the minimum design burst pressure does not exceed the ultimate tensile strength of the liner material as determined in S5.7 and S5.7.1.

S5.4.2.2 The wall thickness of a liner to a Type 2 container shall be at least an amount such that the compressive stress in the sidewall of the finished container at zero pressure shall not exceed 95 percent of the yield strength of the liner as determined in S5.7 and S5.7.1 or 95 percent of the minimum design yield strength shown in S5.7.3. The maximum tensile stress in the liner at service pressure shall not exceed 66 percent of the yield strength.

S5.4.2.3 Stresses at the end designs at internal pressures between no more than 10 percent of service pressure and service pressure shall be less than the maximum stress limits in the sidewall as prescribed above.

S5.4.3 *Type 3 containers.* The wall thickness of a liner to a Type 3 container shall be such that the compressive stress in the sidewall of the finished container at zero pressure shall not exceed 95 percent of the minimum yield strength of the liner as determined in S5.7 and S5.7.1 or 95 percent of the minimum design yield strength shown in S5.7.3

S5.4.4 *Type 4 containers.* The wall thickness of a liner to a Type 4 container shall be such that the permeation rate requirements of this specification are met.

S5.5 *Composite reinforcement for Type 2, Type 3, and Type 4 Containers.*

S5.5.1 Compute stresses in the liner and composite reinforcement using National Aeronautics and Space Administration (NASA), *Computer Program for the Analysis of Filament Reinforced Metal-Wound Pressure Vessels,* N67–12097 (NASA CR–72124) (May 1966), or its equivalent.

S5.5.2 The composite overwrap shall meet or exceed the following composite reinforcement stress ratio values shown in Table 3.

S5.6 *Thermal treatment.*

S5.6.1 *Steel containers or liners.*

S5.6.1.1 After all metal forming and welding operations, completed containers or liners shall be uniformly and properly heat treated under the same conditions of time, temperature and atmosphere prior to all tests.

S5.6.1.2 All containers or liners of steel grades ''Chrome-Molybdenum'' or ''Carbon Boron'' shall be quenched in a medium having a cooling rate not in excess of 80 percent that of water. ''Carbon-Manganese'' steel grades shall be normalized and do not require tempering after normalizing.

S5.6.1.3 All steel temperature on quenching shall not exceed 926° C (1700° F).

S5.6.1.4 All containers or liners or steel grades ''Chrome-Molybdenum'' or ''Carbon Boron'' shall be tempered after quenching at a temperature below the transformation ranges, but not less than 482° C (900° F) for ''Carbon-Boron'' steel or 565° C (1050° F) for ''Chrome-Molybdenum'' steel. ''Carbon Manganese'' steel grades do not require tempering after normalizing.

S5.6.2 *Aluminum containers or liners (seamless and welded).* After all forming and welding operations, aluminum containers or liners shall be solution heat treated and aged to the T6 temper. The liner and composite overwrap shall meet the cycle life and strength requirements set forth in S7.1 and S7.2 of this standard.

S5.7 *Yield strength, tensile strength, material elongation (metal containers and metal liners only).* To determine yield strength, tensile strength, and elongation of the material, cut two specimens from one container or liner. The specimen either has (a) a gauge length of 50 mm (2 inches) and a width not over 38 mm (1.5 inches), or (b) a gauge length of four times the specimen diameter, provided that a gauge length which is at least 24 times the thickness with a width not over 6 times the thickness is permitted when the liner wall is not over 5 mm (3/16 inch) thick. The specimen shall not be flattened, except that grip ends may be flattened to within 25 mm (1 inch) of each end of the reduced section. Heating of specimens is prohibited.

S5.7.1 *Yield strength.* The yield strength in tension shall be the stress corresponding to a permanent strain of 0.2 percent based on the gauge length.

S5.7.1.1 The yield strength shall be determined by either the ''offset'' method or the ''extension under load'' method as prescribed by *Standard Test Methods for Tension Testing of Metallic Materials,* ASTM E8 1993.

S5.7.1.2 In using the ''extension under load'' method, the total strain or ''extension under load'' corresponding to the stress at which the 0.2 percent permanent strain occurs may be determined by calculating the elastic extension of the gauge length under appropriate load and adding thereto 0.2 percent of the gauge length. Elastic extension calculations shall be based on an elastic modulus of 69 GPa (10,000,000 psi) for aluminum, or 207 GPa (30,000,000 psi) for steel. If the elastic extension calculation does not provide a conclusive result, the entire stress strain diagram shall be plotted and the yield strength determined from the 0.2 percent offset.

S5.7.1.3 For the purpose of strain measurement, the initial strain is set while the test specimen is under a stress of 41 MPa (6,000 psi) for aluminum, and 83 MPa (12,000 psi) for steel. The strain indicator reading is set at the calculated corresponding strain.

S5.7.1.4 Cross-head speed of the testing machine is 3.2 mm (1/8 inch) per minute or less during yield strength determination.

S5.7.2 *Elongation.* Elongation of material, when tested in accordance with S5.7, shall be at least 14 percent for aluminum or at least 20 percent for steel; except that an elongation of 10 percent is acceptable for both aluminum and steel when the authorized specimen size is 24t gauge length x 6t wide, where ''t'' equals specimen thickness.

S5.7.3 *Tensile strength.* Tensile strength shall not exceed 725 MPa (105,000 psi) for ''Carbon Manganese'' and 966 MPa (140,000 psi) for ''Chrome-Molybdenum'' and ''Carbon-Boron.''

S6 *General requirements.*

S6.1 Each passenger car, multipurpose passenger vehicle, truck, and bus that uses CNG as a motor fuel shall be equipped with a CNG fuel container that meets the requirements of S7 through S7.4.

S6.2 Each CNG fuel container manufactured on or after March 27, 1995 shall meet the requirements of S7 through S7.4.

S7 *Test requirements.* Each CNG fuel container shall meet the applicable requirements of S7 through S7.4.

S7.1 *Pressure cycling test at ambient temperature.* Each CNG fuel container shall not leak when tested in accordance with S8.1.

S7.2 *Hydrostatic burst test.*

S7.2.1 Each Type 1 CNG fuel container shall not leak when subjected to burst pressure and tested in accordance with S8.2. Burst pressure shall be not less than 2.25 times the service pressure for non-welded containers when analyzed in accordance with the stress ratio requirements of S5.4.1, and shall not be less than 3.5 times the service pressure for welded containers.

S7.2.2 Each Type 2, Type 3, or Type 4 CNG fuel container shall not leak when subjected to burst pressure and tested in accordance with S8.2. Burst pressure shall be no less than the value necessary to meet the stress ratio requirements of Table 3, when analyzed in accordance with the requirements of S5.5.1.

TABLE THREE.—STRESS RATIOS

Material	Type 2	Type 3	Type 4
E-Glass	2.65	3.5	3.5
S-Glass	2.65	3.5	3.5
Aramid	2.25	3.0	3.0
Carbon	2.25	2.25	2.25

S7.3 *Bonfire test.* Each CNG fuel container shall be equipped with a pressure relief device. Each CNG fuel container shall completely vent its contents through a pressure relief device or shall not burst while retaining its entire contents when tested in accordance with S8.3.

S7.4 *Labeling.* Each CNG fuel container shall be permanently labeled with the information specified in paragraphs (a) through (h) of this section. Any label affixed to the container in compliance with this section shall remain in place and be legible for the manufacturer's recommended service life of the container. The information shall be in English and in letters and numbers that are at least 6.35 mm (¼ inch) high.

(a) The statement: ''If there is a question about the proper use, installation, or maintenance of this container, contact___________________,'' inserting the *CNG fuel container manufacturer's name, address, and telephone number.*

(b) The statement: ''Manufactured in ___________,'' inserting the month and year of manufacture of the CNG fuel container.

(c) The statement: ''Service pressure ___________ kPa, (___________ psig).''

(d) The symbol DOT, constituting a certification by the CNG container manufacturer that the container complies with all requirements of this standard.

(e) The container designation (e.g., Type 1, 2, 3, 4).

(f) The statement: ''CNG Only.''

(g) The statement: ''This container should be visually inspected after a motor vehicle accident or fire and at least every 36 months or 36,000 miles, whichever comes first, for damage and deterioration.

(h) The statement: ''Do Not Use After ___________'' inserting the month and year that mark the end of the manufacturer's recommended service life for the container.

S8 *Test conditions: fuel container integrity.*

S8.1 *Pressure cycling test.* The requirements of S7.1 shall be met under the conditions of S8.1.1 through S8.1.4.

S8.1.1 Hydrostatically pressurize the CNG container to the service pressure, then to not more than 10 percent of the service pressure, for 13,000 cycles.

S8.1.2 After being pressurized as specified in S8.1.1, hydrostatically pressurize the CNG container to 125 percent of the service pressure, then to not more than 10 percent of the service pressure, for 5,000 cycles.

S8.1.3 The cycling rate for S8.1.1 and S8.1.2 shall be any value up to and including 10 cycles per minute.

S8.1.4 The cycling is conducted at ambient temperature.

S8.2 *Hydrostatic burst test.* The requirements of S7.2 shall be met under the conditions of S8.2.1 through S8.2.2.

S8.2.1 Hydrostatically pressurize the CNG fuel container, as follows: The pressure is increased up to the minimum prescribed burst pressure determined in S7.2.1 or S7.2.2, and held constant at the minimum burst pressure for 10 seconds.

S8.2.2 The pressurization rate throughout the test shall be any value up to and including 1,379 kPa (200 psi) per second.

S8.3 *Bonfire test.* The requirements of S7.3 shall be met under the conditions of S8.3.1 through S8.3.10.

S8.3.1 The CNG fuel container is filled with compressed natural gas and tested at (1) 100 percent of service pressure and (2) 25 percent of service pressure. Manufacturers may conduct these tests using the same container or with separate containers.

S8.3.2 The CNG fuel container is positioned so that its longitudinal axis is horizontal. Attach three thermocouples to measure temperature on the container's bottom side along a line parallel to the container longitudinal centerline. Attach one at the midpoint of the container, and one at each end at the point where the dome end intersects the container sidewall. Subject the entire length to flame impingement, except that the flame shall not be allowed to impinge directly on any pressure relief device. Shield the pressure relief device with a metal plate.

S8.3.3 If the test container is 165 cm (65 inches) in length or less, place it in the upright position. Attach three thermocouples to measure temperature on the container's bottom side along a line which intersects the container longitudinal centerline. Attach one at the midpoint of the bottom of the container, and one each at the point where the dome end intersects the container sidewall. Subject the container to total fire engulfment in the vertical. The flame shall not be allowed to impinge directly on any pressure relief device. For containers equipped with a pressure relief device on one end, the container is positioned with the relief device on top. For containers equipped with pressure relief devices on both ends, the bottom pressure relief device shall be shielded with a metal plate.

S8.3.4 The lowest part of the container is suspended at a distance above the fire such that the container bottom surface temperatures specified in S8.3.6 are achieved.

S8.3.5 The CNG fuel container is tested with the valve and pressure relief device or devices in place.

S8.3.6 The fire is generated by any fuel that maintains a flame temperature between 850 and 900 C for the duration of the test, as verified by each of the three thermocouples in S8.3.2 or S8.3.3.

S8.3.7 The fuel specified in S8.3.6 is such that there is sufficient fuel to burn for at least 20 minutes. To ensure that the sides of the fuel container are exposed to the flame, the surface area of the fire on a horizontal plane is such that it exceeds the fuel container projection on a horizontal plane by at least 20 cm (8 inches) but not more than 50 cm (20 inches).

S8.3.8 Time-pressure readings are recorded at 30 second intervals, beginning when the fire is lighted and continuing until the container is completely tested.

S8.3.9 The CNG fuel container is exposed to the bonfire for 20 minutes or until its contents are completely vented.

S8.3.10 The average wind velocity at the container is any velocity up to and including 2.24 meters/second (5 mph).

[59 FR 49021, Sept. 26, 1994; 59 FR 66776, Dec. 28, 1994; 60 FR 37843, July 24, 1995; 60 FR 57948, Nov. 24, 1995; 61 FR 19204, May 1, 1996; 61 FR 47089, Sept. 6, 1996]

§571.500 Standard No. 500; Low-speed vehicles.

S1. *Scope.* This standard specifies requirements for low-speed vehicles.

S2. *Purpose.* The purpose of this standard is to ensure that low-speed vehicles operated on the public streets, roads, and highways are equipped with